N92-22775

NICKEL HYDROGEN CELL DESIGN

A DESIGNER'S ASPECT

Raymond Rehm

Nickel Hydrogen Battery Cells

October 30, 1991

Gates Energy Products

Gates Aerospace Batteries

1. Scope

The following paper is designed to give added insight into the methodology of Nickel Hydrogen cell design and aid in deciphering the battery cell reference guide which has been distributed to many of GAB's current and potential customers. Due to certain information's proprietary nature, and sensitivity to international restriction's this paper is intentionally vague in some areas.

2. Cell Design

In many aspects the cell design for Gates' nickel hydrogen has been established and is not readily changeable. These areas include stack compression and support, cell seal, closure weld method and materials used for components. Gates has been granted patents for the ceramic seal design (patent number 4,904,551 issued 2/27/90) and two for the support design (patent numbers 4,950,564 issued 8/21/90 and 5,002,842 issued 3/26/91).

Gates currently utilizes the weld rings to act as the compression medium within the cell. The cell stack is compressed via a welding fixture while the cell is undergoing the final closure weld. This method of compression deloads the core and compresses the stack between the two weld rings in contact with the exterior endplates. At this point the core is used solely to electrically separate the positive and negative lead bundles.

Two domes are welded to a central cylinder which is manufactured in lengths up to ten feet. The cylinder is subsequently cut to the length required to accommodate the electrode stack and maintain compression in the welded condition. This method of compression alleviates concerns of deep drawing Nickel Alloy 718 to meet the lengths required by long electrode stacks for higher capacity cells.

The cell sealing method is performed via the GAB patented ceramic seal. This seal has demonstrated 164,000 hydraulic pressure cycles, from 0 to 1000 PSIG, without affecting the cells' hermeticity requirements.

Gates currently utilizes TIG welding for cell closure. This method has been proven reliable to the same cycling regime listed for the ceramic seal.

The component materials utilized in the manufacture of the nickel hydrogen cells have been chosen based on their individual capabilities to withstand the caustic environment of the cell for a design life in excess of 15 years without degradation. The components have also demonstrated capabilities to cycle beyond 10,000, 70 % DoD and 27,000 40 % DoD charge/discharge cycles in low earth orbit regimes at pressures up to 1000 psig of hydrogen.

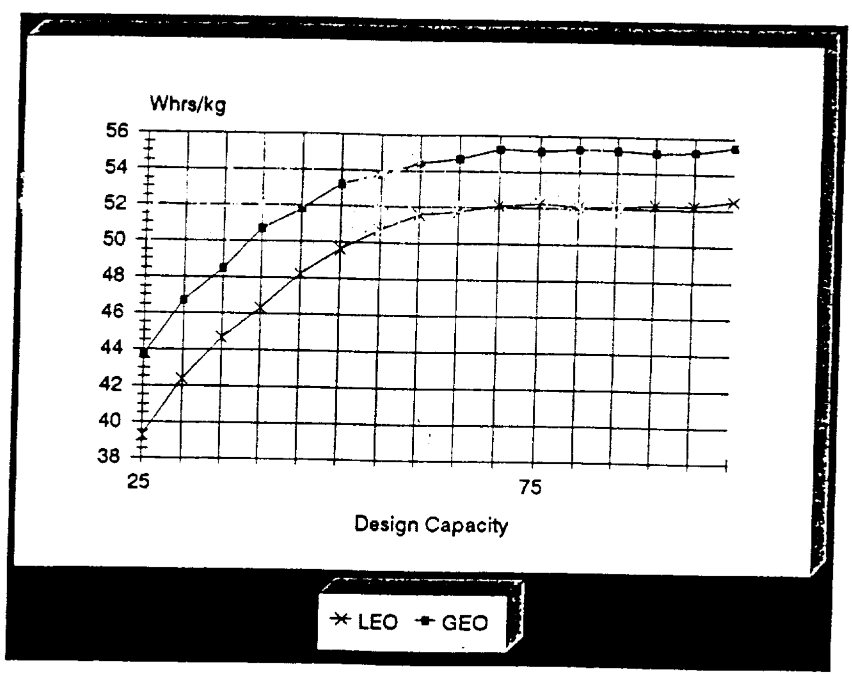

Figure 1. Specific Energy for Gates 3.5" Cells

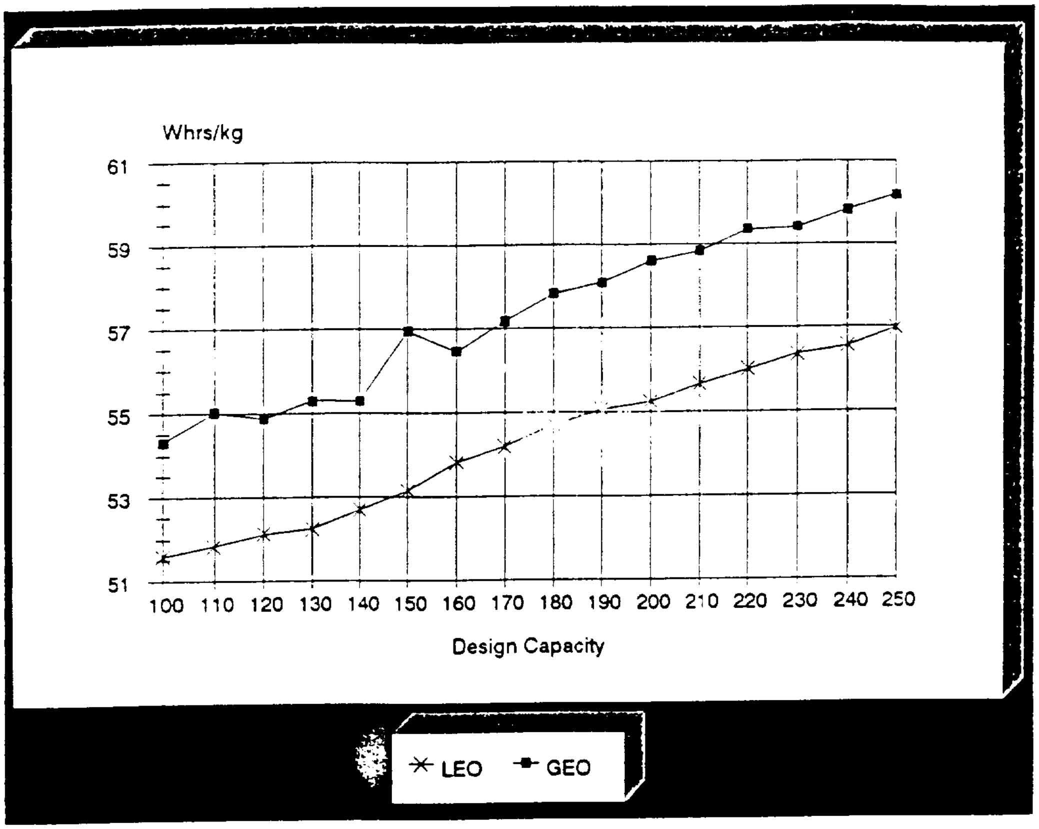

Figure 2. Specific Energy for Gates 4.5" Cells

3. Cell Stacking Design

Each satellite operates differently in accordance with the operations which must be maintained during the charge/discharge cycle. Low Earth Orbit (LEO) and Geosynchronous Orbit (GEO) have differing cycle life and cycle requirements.

In a typical Geosynchronous orbit a cell will perform approximately 90 cycles in a year and generally less than 1500 cycles in the satellites' operational life. In a typical Low Earth Orbit, a cell will go through a charge/discharge cycle every ninety minutes. This relates to approximately 5850 cycles per year. A typical LEO satellite operational life is in excess of 5 years. For the reason, the LEO regime is considered the more stringent of the two.

A cell which can meet the rigid requirements of the LEO is more than adequate to meet the GEO satellite regime. The benefit of using a GEO satellite cell design is that the design can save enough weight to amount to pounds at the battery level. Conversely, the GEO cell design will not necessarily meet the requirements of a LEO satellite. The difference between the two, as it pertains to the cell design, is the rapidity and rate of charge/discharge and the amount of oxygen generated as a result of the stack design at the higher recharge rate required by the LEO regime. Oxygen generation and recombination is not problematic for a GEO regime from the aspect of lower recharge rates and the number of cycles required for design life.

For the reasons outlined above a stack design which is sufficient for one orbit would not necessarily be recommended for the other. Gates currently employs two designs which can be broken down to a LEO (recirculating) and a GEO (back-to-back) cell stack design. The GEO cell design also incorporates a positive electrode which is nominally thicker than the LEO cell electrode design. This makes it possible to reduce the number of electrode pairs needed to meet the capacity required for the application. The difference in the Volumetric and Mass Energies between the two cell configurations can be seen in Figures I through IV.

4. Capacity

Another major point of confusion is the question of cell capacity. There are as many ways of determining "Nameplate" as there are customers who buy NiH_2 battery cells. For this reason Gates has incorporated a singular method of determining the nameplate which is listed as the cells' cataloged nameplate. The cell nameplate is closely aligned to the nominal cell capacity output at a C/2 discharge to 1.0 volt at $10^{o}C$ after a C/10 charge for 16 hours. The cell characteristics change as a function of temperature, charge, and discharge rates. The requirements of nominal capacity, minimum average cell capacity, and minimum cell capacity are also concerns which must be resolved prior to signing up to any particular design.

When a customer asks for cell with a "nameplate" capacity of 63 Ah, immediate attention must be focused on the conditions under which the 63 Ah must be provided. The Gates nameplate for the cell mentioned may be anywhere from 55 to 80 Ah, but we are committed to delivering the lightest cell that will meet the requirements of your application for the life of the satellite. A sample of cell capacity design analysis will be demonstrated in the presentation.

Gates utilizes the experience gained in over 25 years of development and manufacture of Nickel Cadmium and Nickel Hydrogen as well as testing and in-flight use to calculate the beginning-of-life capacity required to assure adequate end-of-life capacity for the application. This information (over 1,000,000 cell cycles) includes capacity based on cell temperature, discharge rate, charge/discharge regime, previous usage, and point-in-life. The information that has been accumulated coupled with the data management systems available in today's computer systems, allows Gates to project cell responses to various normal and abnormal cell uses.

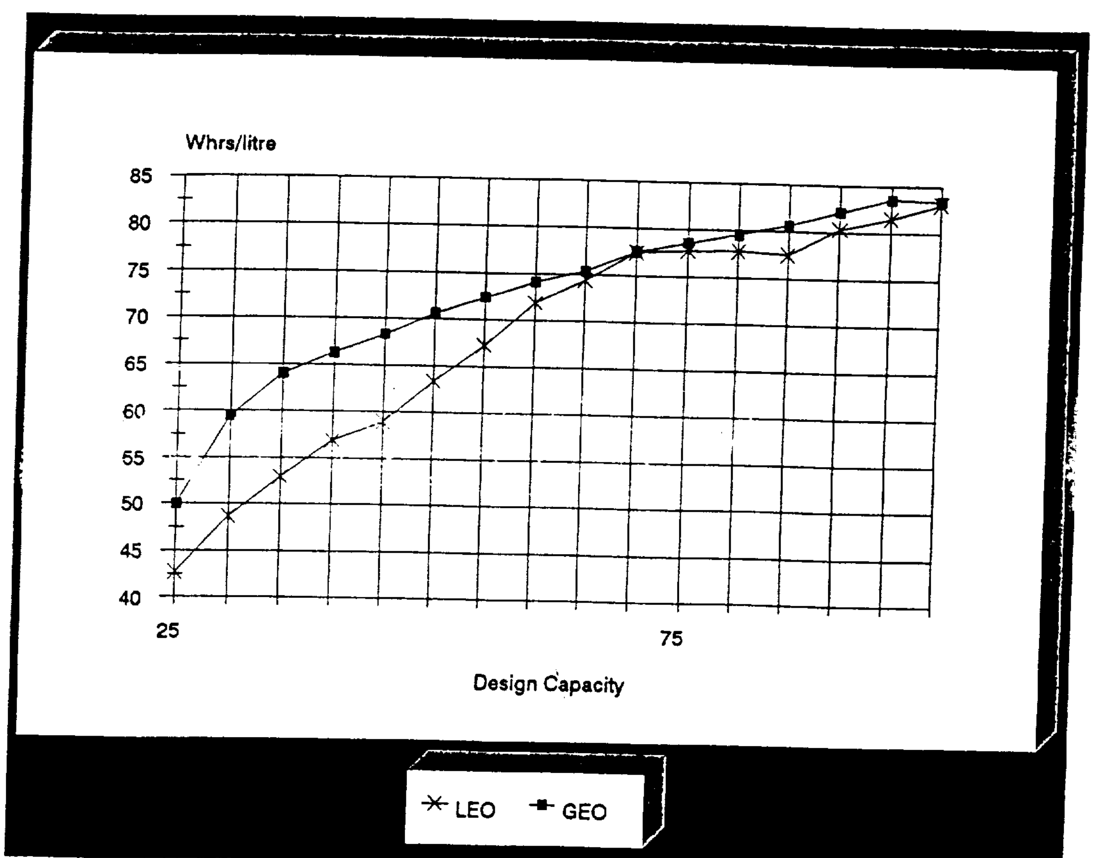

Figure 3. Energy Density of Gates 3.5" Cells

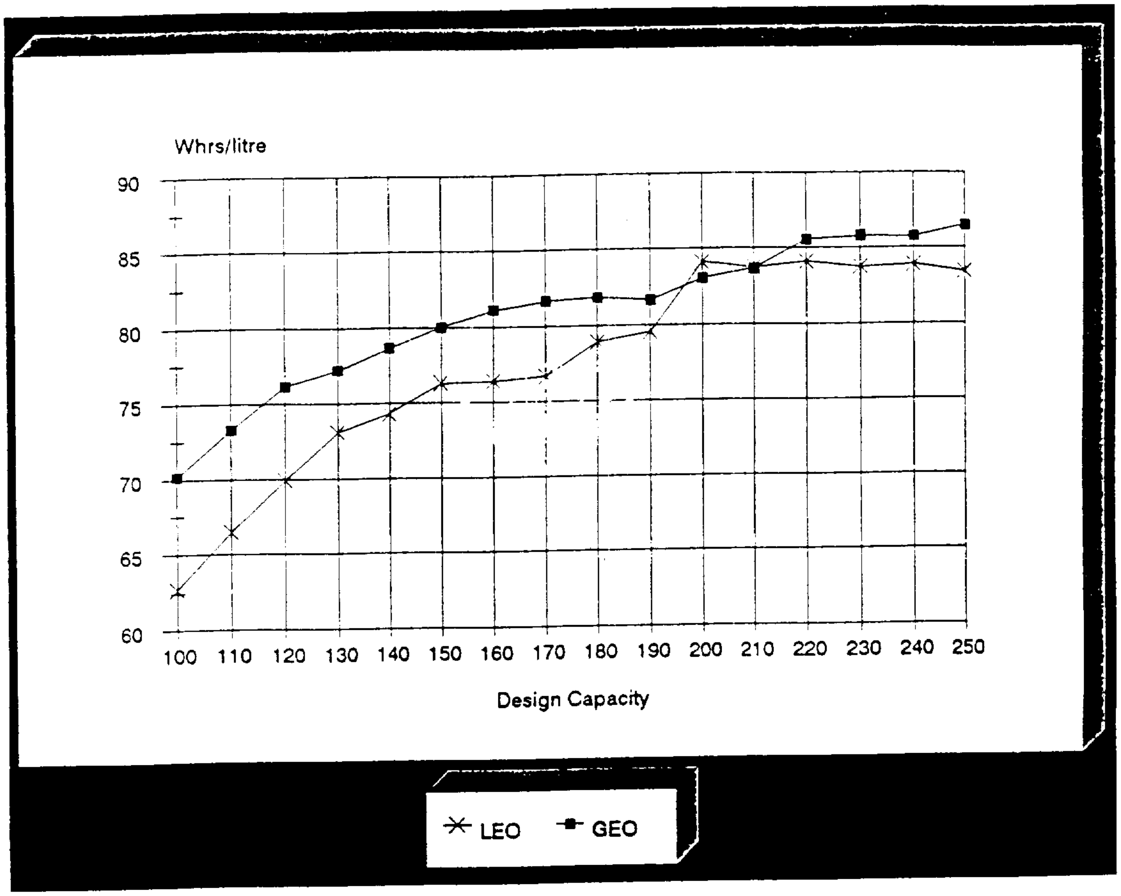

Figure 4. Energy Density of Gates 4.5" Cells

5. Dynamic Response

The cells' response to the dynamic environments of launch are a major concern to the satellite industry. The satellite will be subjected to extreme vibration and acceleration, and potentially to dynamic shock. In qualification for flight use, the customer frequently requires that a test for response to these phenomena be performed. The ability of the cell to perform in these dynamic environments is based on the cells' relative rigidity. The internal components are being tested to assure that they are not being detrimentally compressed and released. This is a test to prove that the compression method used for the cell maintains the stack in compression for the environment that the cell will see during launch. A wide fluctuation in voltage caused by vibration would indicate that the electrode stack is inadequately constrained within the cell. By using the endplates on either end of the cell stack in compressive contact with the weld rings, Gates is confident of the cells' ability to meet the dynamic requirements of launch and in fact has met the qualification requirements for flight on expendable vehicles.

6. Conclusions

In making a cell reference guide available to the general customer pool, the supplier takes on many risks, including the chance that the guide will be used as a rigid document by which to plan the end item weight of the battery component of the satellite. This can be performed if the guide is used as it is intended but there is more to be considered than the "nameplate" and the weight. Use the guide to assess the approximate requirements for the application and decide if there is adequate margin for weight. If you have any questions on how the guide is intended to be used, contact the cell supplier for further information.